

Dames & Moore Job Number 16550-005-031
May 17, 1993

SOLUTE TRANSPORT ANALYSIS
DUMP LEACH AREA NO. 1
MERCUR GOLD MINE, UTAH
FOR
BARRICK RESOURCES (USA), INC.

 **DAMES & MOORE**



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May 17, 1993

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Solute Transport Analysis
Dump Leach Area No. 1
Mercur Gold Mine, Utah
For Barrick Resources (USA), Inc.
Job No. 16550-005-031

Dear Mr. Eurick:

The attached report provides two methods of solute transport analysis applied to the evaluation of potential impacts to ground water that could occur by seepage from Dump Leach Area No. 1 (DLA#1). Barrick Resources (USA), Inc. (Barrick) is preparing final designs for the capping of DLA#1. Utah Division of Water Quality (DWQ) expressed concern that natural infiltration from rain and snow could accumulate in the dump leach over time. The quality of the water that infiltrates into the dump leach could be affected by reactions with the waste rock and residual process water. DWQ requested that Barrick perform a simple analysis of potential impacts to ground water should a leak of 200,000 gallons per year occur under these conditions.

Several assumptions were made in applying the two methods of solute transport analysis. A review of the assumptions and an explanation of the rationale for the choice of input parameters are provided. If you have any questions, please do not hesitate to contact us.

Sincerely,

DAMES & MOORE

Lori C. Robison
Senior Hydrogeologist

RECEIVED

MAY 21 1993

DIVISION OF
OIL GAS & MINING

TABLE OF CONTENTS

	<u>PAGE</u>
1.0 INTRODUCTION	1
2.0 HYDROGEOLOGIC SETTING	2
2.1 GEOLOGY	2
2.2 HYDROGEOLOGY	2
3.0 INPUT PARAMETERS	4
4.0 BACKGROUND CHEMISTRY	5
5.0 MIXING MODEL	6
5.1 EQUATIONS	6
5.2 ASSUMPTIONS	7
5.3 DILUTION WITH NATURAL INFILTRATION	8
6.0 ONE-DIMENSIONAL SOLUTE TRANSPORT MODEL	9
6.1 EQUATION	9
6.2 RETARDATION	10
6.3 LIMITATIONS	10
7.0 DISCUSSION OF RESULTS	11
7.1 MIXING MODEL	12
7.2 ONE-DIMENSIONAL SOLUTE TRANSPORT MODEL	12
8.0 SUMMARY & CONCLUSIONS	14
9.0 REFERENCES	16

APPENDIX - DATABASE PRINTOUT FROM MIXING MODEL AND OUTPUT FROM ODAST 1-D SOLUTE
TRANSPORT MODEL

LIST OF TABLES

- TABLE 1 - INPUT PARAMETERS FOR SOLUTE TRANSPORT ANALYSES
TABLE 2 - WATER CHEMISTRY FROM LEAK DETECTION SYSTEM-DIA#1
TABLE 3 - WATER CHEMISTRY FROM MONITOR WELL MW-9
TABLE 4 - PREDICTED CONCENTRATIONS FROM THE MIXING MODEL

LIST OF FIGURES

- FIGURE 1 - SCHEMATIC DIAGRAM OF MIXING MODEL COMPONENTS
FIGURE 2 - CONCENTRATION VERSUS DISTANCE - CASE 1
FIGURE 3 - CONCENTRATION VERSUS DISTANCE - CASE 2

1.0 INTRODUCTION

Dump Leach Area No. 1 (DLA#1) at the Barrick Mercur Mine, also referred to as Valley Fill Leach 1, was used for cyanide leaching of low-grade gold ore. Gold recovery by cyanide solution leaching ceased on July 15, 1988. Since this shut down date DLA#1 has undergone neutralization by fresh water flushing and precipitation. Barrick has submitted neutralization, closure, and post-closure monitoring plans for DLA#1 to the Utah Division of Water Quality (written communication to DWQ from Barrick, October 29, 1992), and is in the process of responding to comments by DWQ. Barrick plans to conduct a staged closure for DLA#1 to accommodate interim stockpiling of ore feed-stock during the 1993-1998 period, prior to placement of final topsoil and revegetation.

DWQ expressed concern that once the dump leach is capped, natural infiltration from rain and snow-melt could accumulate within the dump leach over time. The quality of the water that infiltrates into the dump leach could be affected by reactions with the waste rock and residual process water. DWQ requested that Barrick perform a simple analysis of potential impacts to ground water beneath DLA#1 should a leak of 200,000 gallons per year occur. Barrick contracted Dames & Moore to evaluate the potential impacts using analytical transport equations.

DWQ specifically requested a simple analytical approach and not a numerical model. Two analytical solutions were applied to the problem: concentration distributions in a mixing model, and solute transport through advection and dispersion in one-dimension. Two sensitivity cases were run for the mixing model to address uncertainties in the predicted results associated with possible variations in input parameters of hydraulic conductivity and dispersivity. Two cases were run for the solute transport equation to evaluate the effects of transport with and without chemical retardation.

2.0 HYDROGEOLOGIC SETTING

The following information on the hydrogeologic setting is summarized from Dames & Moore (1991) and Getty (1985) site hydrogeologic reports.

2.1 GEOLOGY

The Barrick Mercur Mine is located within the southern portion of the Oquirrh Mountains, a fault-block range within the Basin and Range physiographic province. The range exhibits folded and faulted Paleozoic sedimentary rocks which were locally intruded by Oligocene igneous rocks. Mercur is located on the eastern flank of the Ophir anticline, a north-northwest trending structure.

DLA#1 is situated on locally thin deposits of fine-grained alluvial and colluvial sediments, which are underlain by the Upper Member of the Great Blue Limestone. The limestone dips between 25 to 50 degrees to the northeast and is conformably underlain by the Long Trail Shale. The Lower Member of the Great Blue Limestone lies beneath the Long Trail Shale.

The Upper Member of the Great Blue Limestone consists of limestone beds with numerous shaley limestone and shale interbeds. In monitor well borings, shale interbeds range from a few feet to as much as fifty feet thick. Interbeds do not appear to be laterally continuous. The Long Trail Shale was identified by a change in lithology and color to predominantly darker gray to black shale, shaley limestone and shaley siltstone. The Long Trail Shale has been observed to be continuous and about 100 to 200 feet thick throughout the mine area.

Getty reports that no significant faults were observed in the area of DLA#1. A primary joint set is oriented to the northeast with near vertical dips. A secondary joint set strikes to the northwest and dips steeply to the southwest.

2.2 HYDROGEOLOGY

Fluid movement in both the unsaturated and saturated zones is through fractures, joints, and fissures. Depth to ground water was recorded on drilling reports for borings located west and south of DLA#1 (Getty, 1985). Depth to ground water in monitor well MW-9, located east of the area, is monitored quarterly by Barrick. Ground water is found in saturated low-yielding zones in the Upper Member of the Great Blue Limestone and in the Long Trail Shale. Depths to ground water range from about 100 to 300 feet below ground surface in borings west of DLA#1; from 750 to 770 feet below ground surface in borings south of the site; and 900 feet below ground surface east of the site, in MW-9. The lateral gradient is about

0.15 foot/foot. The local flow direction appears to be east-southeast. The regional flow gradient and direction are structurally controlled, with regional movement down-dip to the northeast, and then southeasterly along the axis of the Pole Canyon Syncline toward Cedar Valley.

Well MW-9 was completed in limestone. Ground water was first encountered at the 1,175 foot depth during drilling; slight increases in yield were observed as drilling approached the 1,200 foot depth. Well test results indicate that the water-bearing zones that were intercepted yield very little water. Specific capacities were measured at 0.03 gpm/ft. The water bearing zones have very poor transmissive capabilities (16 gpd/ft) due to limited hydraulic conductivity, porosity and thickness (estimated at about 30 feet) of water-bearing fracture zones intercepted by the well. Estimates of hydraulic conductivity of 26 ft/yr (0.07 ft/day) reflect ground water flows along fracture zones of limited extent.

Recharge in the area is controlled by geologic structure, and hydrogeologic and topographic features. Recharge to the aquifer beneath DLA#1 results from infiltration of precipitation. Infiltration rates will vary with season due to winter snow-pack storage and spring runoff. Infiltration is greatest during the spring when the winter snow pack thaws, and is least during the winter when recharge is limited by frozen ground and temporary snow-pack accumulation.

3.0 INPUT PARAMETERS

Input parameters were derived from actual field tests and from references in the literature to similar material types. Sensitivity analyses were performed for hydraulic conductivity and dispersivity because of the strong influence these two parameters have on the calculations and because of the degree of uncertainty of true values for each. Both hydraulic conductivity and dispersivity can vary by orders of magnitude. As a result, ranges of calculated values for Darcy velocity, linear velocity, and hydrodynamic dispersion are also presented. Input parameters and the associated numeric values used in the two models are listed in Table 1. The rationale for the choice of each numeric value is also provided.

4.0 BACKGROUND CHEMISTRY

In the solute transport analysis, assumptions are made regarding background water quality and quality of infiltrated water, in order to calculate water quality after mixing. Background water quality was assumed to be similar to ground water monitored in well MW-9. The quality of infiltrated water was assumed to be similar to water monitored in the leak collection system of DLA#1. Monitoring reports were reviewed, and only those constituents that have been assigned Federal primary drinking water maximum contaminant levels (MCLs) and secondary MCLs (SMCLs) were considered. Average values were calculated from reported values for the last three sampling events. Table 2 presents a list of constituents that exceed MCLs in two of the three sampling events. Reported values and the calculated average value for these constituents are presented for both the leak collection system and MW-9. In two instances, the laboratory detection level was higher than the MCL. Two sensitivity cases were evaluated with background values set at 1) the laboratory detection level and 2) zero.

5.0 MIXING MODEL

The equation for the mixing model is presented in a report by the EPA (1989). A cross-sectional diagram depicting the input parameters is shown on Figure 1. Values for input parameters are listed in Table 1.

5.1 EQUATIONS

The mixing model calculates the concentration of a constituent in water (C'_A) based on the following equation:

$$C'_A = \frac{Q_I C_I + Q_A C_A}{Q_I + Q_A}$$

where

Q_I = inflow from infiltration;
 Q_A = inflow from the aquifer;
 C_I = concentration in the infiltrated water; and
 C_A = background concentration in the aquifer.

Inflow from infiltration (Q_I) is calculated by:

$$Q_I = Iwl$$

where

I = infiltration rate;
 w = width of the disposal area perpendicular to flow; and
 l = length of the disposal area parallel to flow.

Note that infiltration includes both seepage and natural recharge-see explanation in Table 1.

Inflow from the aquifer (Q_A) is calculated by:

$$Q_A = K_A A_A i_A$$

where

K_A = hydraulic conductivity of the aquifer;

i_A = hydraulic gradient of the aquifer.

A_A = is the cross sectional area where mixing will occur; and

Hydraulic gradient, $i=dh/dl$, is calculated from the change in hydraulic head (dh) across the projected length (l) of the disposal area (see Figure 1).

Cross sectional area is measured as the width (w) of the disposal area multiplied by the mixing depth:

$$A_A = wH$$

where H = mixing depth.

The mixing depth is estimated by the equation:

$$H = \sqrt{2\alpha_T l} + B(1 - e^{-u})$$

The factor u is defined as:

$$u = \frac{Il}{Bv_A}$$

where

B = total thickness of aquifer;

v_A = Darcy velocity in the aquifer -- $K_A i_A$; and

α_T = transverse dispersivity in aquifer.

Note that if H is greater than B , then H is equal to B .

5.2 ASSUMPTIONS

This simplified mixing model does not take into account any dilution that would occur in the unsaturated zone. The unsaturated zone, or vadose zone, ranges in thickness from about 200 feet on the west side of DLA#1 to about 900 feet on the

east side. Although DLA#1 is constructed with low permeability liners, some seepage is expected to occur through the base of the containment system. Natural recharge will migrate to the area beneath the dump leach maintaining equilibrium conditions for the moisture content in the vadose zone.

5.3 DILUTION WITH NATURAL INFILTRATION

The percentage of dilution by mixing with infiltrated water was calculated from inflow of seepage divided by the sum of inflow from seepage and natural infiltration.

6.0 ONE-DIMENSIONAL SOLUTE TRANSPORT MODEL

A one-dimensional, analytical, solute transport solution was applied using equations presented by Javandel and others (1984) that were translated into computer program ODAST. This program is available through the International Ground Water Modeling Center as part of the AGU-10 Program Package (Version 2.1, August 1990). The solute transport program considers convection, dispersion, decay and adsorption. Two case studies were analyzed for the range of hydraulic conductivities presented on Table 1. Transport with and without retardation were compared in each case study.

6.1 EQUATION

The transport equation is based on the law of conservation of mass. Assumptions for this solution are that the porous medium is homogeneous and isotropic, that the medium is saturated, that the flow is steady-state, and that Darcy's law applies. Flow is described by the average linear velocity, which carries the dissolved substance by advection.

The one-dimensional form of the advection-dispersion equation is presented in Freeze and Cherry (1979) as:

$$D_1 \frac{\partial^2 C}{\partial l^2} - v_1 \frac{\partial C}{\partial l} = \frac{\partial C}{\partial t}$$

where

l = curvilinear coordinate direction taken along the flowline;

v_1 = average linear groundwater velocity;

D_1 = coefficient of hydrodynamic dispersion in the longitudinal direction, along the flow path; and

C = solute concentration.

The coefficient of hydrodynamic dispersion is expressed in terms of two components:

$$D_1 = \alpha_1 v_1 + D^*$$

where α_1 is longitudinal dispersivity; and
 D^* is the coefficient of molecular diffusion for the solute in the porous medium.

6.2 RETARDATION

The following discussion on retardation is summarized from Freeze and Cherry (1979). The transfer by adsorption or other chemical processes of contaminant mass from the pore water to the solid part of the porous medium, while flow occurs, causes the advance rate of the contaminant front to be retarded. The retardation of the front relative to the bulk mass of water is described by the relation:

$$\frac{v_l}{v_c} = 1 + \frac{\rho_b}{n} \cdot K_d$$

where

v_l = average linear velocity of the groundwater;

v_c = the velocity of the $C/C_o = 0.5$ point on the concentration profile of the retarded constituent;

C/C_o = is the concentration at the output (C) divided by the background concentration (C_o);

K_d = the distribution coefficient;

n = porosity; and

ρ_b = bulk mass density.

When a mixture of reactive contaminants enters groundwater, each species will travel at a rate depending on its relative velocity, v_l/v_c . After a given time the original contaminant plume will have segregated into different zones each advancing in the same direction at different velocities (Freeze and Cherry, 1979).

6.3 LIMITATIONS

The one-dimensional solution for transport of dissolved constituents is of limited use in the analysis of field problems because dispersion occurs in transverse directions as well as in the longitudinal direction. The one-dimensional transport equations are based on idealized conditions, such as continuous point source and uniform flow, which are uncommon in most field situations. However, in simple hydrogeologic settings, the equations are used to obtain preliminary estimates of the migration patterns that may arise from small contaminant spills.

7.0 DISCUSSION OF RESULTS

Reports on water chemistry indicated five constituents in water from the leak detection system exceeded MCLs:

<u>Constituent</u>	<u>Average concentration (ppm)</u>	<u>MCL or SMCL(ppm)</u>
arsenic	2.57	0.05
manganese	1.21	0.05
total dissolved solids (TDS)	2561	500-1,000
sulfate	1432	250-500
thallium	0.081	0.002

These constituents were considered in the solute transport analyses.

Water chemistry from well MW-9 was used as background or initial concentrations for ground water in the mixing model. Average concentrations from MW-9 included:

<u>Constituent</u>	<u>Average concentration (ppm)</u>	<u>MCL or SMCL(ppm)</u>
arsenic	<0.01	0.05
manganese	0.033	0.05
total dissolved solids (TDS)	460	500-1,000
sulfate	87	250-500
thallium	<0.01	0.002

Reported concentrations for arsenic and thallium were less than the laboratory detection limit of 0.01 ppm. In the mixing model calculations the background concentration for these two constituents was considered to be 0.0 ppm.

Infiltration water was considered to be pure, without any of the five constituents of interest.

Details of the data calculations for the mixing model and computer output from the solute transport model are presented in the attached Appendix.

7.1 MIXING MODEL

Details of the data calculations for the mixing model are presented in the attached Appendix. Predicted results are listed in Table 4.

The mixing model solution was applied twice to simulate both mixing with infiltrated water in the unsaturated zone and mixing with ground water. Dilution by mixing water in the leak detection system with infiltrated water reduced the outflow concentrations to approximately 19 percent of the initial concentrations in the leak detection system. (This percentage was calculated from inflow from seepage of 73 ft³/day divided by the sum of inflow from seepage and natural infiltration of 306 ft³/day.) These reduced concentrations were then used as input for mixing with ground water.

In the analysis of mixing with ground water, two cases were examined. In Case 1 a hydraulic conductivity value of 0.07 ft/day and a transverse dispersivity value of 12 ft were used to simulate results based on the low end of the range of values presented in Table 1. Case 2 applied a hydraulic conductivity value of 0.3 ft/day and a transverse dispersivity value of 20 ft to represent the high end of the range. Case 1 resulted in larger concentrations compared to Case 2 due to water moving through the aquifer at a slower rate and less predicted spread or dispersion. Calculated concentrations included:

<u>Constituent</u>	<u>Case 1 ppm</u>	<u>Case 2 ppm</u>	<u>MCL or SMCL ppm</u>
arsenic	0.11*	0.03*	0.05
manganese	0.08	0.05	0.05
TDS	468	462	500-1,000
sulfate	130	99	250-500
thallium	0.004*	0.001*	0.002

*Background concentrations were assumed to be zero, because reported values were less than laboratory detection limits of 0.01.

Calculated concentrations of arsenic, manganese, and thallium exceeded drinking water standards by about a factor of two given the assumptions of Case 1. Calculated concentrations for all five constituents were at or below drinking water standards for Case 2.

7.2 ONE-DIMENSIONAL SOLUTE TRANSPORT MODEL

The one-dimensional solute transport model provided relative concentrations--outflow concentrations divided by background concentrations--for specified data

input of time and distance from the source. Two sensitivity cases were evaluated using hydraulic conductivity values of 0.07 and 0.3 ft/day. Two hydrodynamic dispersion D_1 values were used as this input parameter is directly related to hydraulic conductivity. Both sensitivity cases were examined with and without chemical retardation.

Profiles of relative concentration (C/C_0) versus distance downgradient from the edge of the dump leach are presented on Figures 2 and 3. Data from two time periods are shown as decay curves on the diagrams: 10 and 20 years. These curves illustrate predicted distances contaminants migrate through processes of advection and dispersion for given time periods. In Case 1, after 10 years the initial concentration is reduced by 50 percent at a distance of less than 400 feet from the source. After 20 years the contaminant front, representing 50 percent of initial concentrations, has migrated to about 750 feet from the source.

By comparison, for Case 2, the larger conductivity results in an increase in travel distance as well as an increase of attenuation with time. After 10 years the initial concentration is reduced by 50 percent at a distance of about 1,700 feet from the source. After 20 years the contaminant front, representing 50 percent of initial concentrations, has migrated to about 3,300 feet from the source.

Dramatic decreases in distances contaminants traveled are predicted when retardation is considered, as shown on Figures 2 and 3. Given the same hydrogeologic input parameters, the relative concentration of 50 percent of initial concentration is encountered at less than 50 feet in Case 1 and less than 300 feet in Case 2 after 20 years.

8.0 SUMMARY & CONCLUSIONS

Barrick Mercur Mine used DLA#1 for cyanide leaching of low-grade gold ore. Barrick plans to conduct a staged closure for DLA#1 to accommodate interim stockpiling of ore feed-stock during the 1993-1998 period, prior to placement of final topsoil and revegetation.

DWQ expressed concern that once the dump leach is capped, natural infiltration from rain and snow-melt could accumulate within the dump leach over time; as such, the quality of the water that infiltrates into the dump leach could be affected by reactions with the waste rock and residual process water. Barrick contracted Dames & Moore to evaluate the potential impacts to ground water beneath DLA#1 should a leak of 200,000 gallons per year occur.

Two analytical solutions were applied to the problem: concentration distributions in a mixing model, and contamination migration through advection and dispersion in a one-dimensional solute transport model. Two sensitivity cases were run for the mixing model to address uncertainties in the predicted results associated with possible variations in input parameters of hydraulic conductivity and dispersivity. Solute transport was analyzed with and without chemical retardation. Water quality in the leak detection system beneath DLA#1 was analyzed to determine the constituents of concern. Five constituents were found to exceed either primary or secondary drinking water standards: arsenic, manganese, TDS, sulfate, and thallium.

Application of simple mixing model principals and one-dimensional analysis of solute transport, with the assumptions stated in the text, indicates the following:

- Quality of 200,000 gallons of released water should improve when mixed with natural infiltration waters. Calculations indicated about 80 percent reduction from initial concentrations.
- Quality of the released water should improve when initially mixed with ground water. Calculations indicate about a 96 percent reduction from initial concentrations due to the combined effects of mixing with natural infiltration and mixing with ground water.
- Concentrations should be reduced with distance from the source, through processes of advection and dispersion. Calculations indicate that assuming a continuous supply over 20 years the contaminant front will extend about 800 to 3,300 feet downgradient from the source.

- Chemical reactions such as adsorption should have a radical influence on the migration of contaminants. Calculations indicate that contaminant transport distances were reduced when retardation was considered. Predicted distances that arsenic traveled through time were reduced by about 93 percent with the effects of retardation.

Although these simple analytical solutions have restrictive assumptions, they clearly demonstrate that should seepage occur it is unlikely that ground water will be impacted at large distances (miles) downgradient from the source.

9.0 REFERENCES

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Barrick Mercur Mine
16550-005-031
Report Dump Leach Area No. 1
May 17, 1993

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Canyon Dam Site, Mercur Gold Project, Tooele County, Utah, January 15,
1982.

TABLE 1
INPUT PARAMETERS FOR SOLUTE TRANSPORT ANALYSES

Parameter	Chosen Value	Justification
Hydraulic Conductivity K_a	0.07-0.30 ft/day	Low range is calculated conductivity from well test analysis of MW-9: 26 ft/yr, which equals 0.07 ft/day (Dames & Moore, 1990). High range is logarithmic mean of conductivities from packer tests in BH-25 (Woodward Clyde, 1982a and b). This value has been used as a representative value for hydraulic conductivity for the area (Dames & Moore, 1991b and d, 2-D model for DLA#3; and Dames & Moore 1991a and c, fracture study).
Gradient i	0.15 ft/ft	Three point calculation from reported ground water elevations in GA-26, CD-4, and MW-9 (Dames & Moore, 1990).
Darcy Velocity v_a	0.0105-0.045 ft/day	Calculation of $v_a = Ki$.
Average Linear Velocity v_l	0.105-0.45 ft/day	Calculation of $v_l = (Ki)/n$. Assume typical porosity (n) of limestone equals 0.1 (Heath, 1983).
Aquifer Thickness B	400 ft	Thickness of standing water in CD-4: 1165 ft (total depth of boring) minus 751 (depth to water) = 415 ft (Getty, 1985).
Longitudinal Dispersivity α_l	60 ft	Longitudinal dispersivity was predicted based on Gelhar (1986) diagram relating dispersivity to the length of travel. Gelhar plots data from case studies reporting dispersivity and length of travel; the spread of data forms a decay curve. Assuming a maximum length of travel of 500 ft in 20 years, the corresponding point on the decay curve results in longitudinal dispersivity of 60 ft.
Transverse Dispersivity α_t	12-20 ft	Transverse dispersivity was predicted based on ratios of 1:3 and 1:5 for transverse/longitudinal dispersivities (Mercer and Faust, 1981).
Molecular Diffusion D^*	1×10^{-4} ft ² /day	Diffusion coefficients typical for coarse grained unconsolidated materials presented as 1×10^{-10} m ² /s $\approx 1 \times 10^{-4}$ ft ² /day.

TABLE 1 (Continued - 2)

Parameter	Chosen Value	Justification
Hydrodynamic Dispersion D_1	6.3-27 ft ² /day	Calculate $D_1 = \alpha_1 v_1 + D^*$. The value for D^* is assumed to be negligible.
Infiltration Rate I	2.1×10^{-3} ft/day	Rate of 200,000 gal/yr, or 73 ft ³ /day (given by DWQ), over the area of the dump leach (180,000 ft ²), which calculates to 4×10^{-4} ft/day. Plus rate of infiltration from precipitation 1.7×10^{-3} ft/day (Feltis, 1967; and Dames & Moore, 1991, input parameter for 2-D model).
Length of Source Area L	600 ft	Approximate length of DLA#1 based on cross sectional diagram (Barrick Resources, Dump Leach No. 1, Proposed Decommission Plan).
Width of Source Area w	300 ft	Approximate width of DLA#1 based on cross sectional diagram (Barrick Resources, Dump Leach No. 1, Proposed Decommission Plan).
Retardation Factor R	15-20 dimensionless	Range of retardation factors calculated for arsenic in bedrock (Dames & Moore, 1993).

Barrick Mercur Mine
16550-005-031
Report Dump Leach Area No. 1
May 17, 1993

TABLE 2
WATER CHEMISTRY FROM LEAK DETECTION SYSTEM-DLA#1

Date Sampled	January 15, 1992	July 14, 1992	January 26, 1993	Average	Federal Primary and Secondary MCLs
arsenic	2.8	2.93	1.98	2.57	0.05
manganese	1.44	0.796	1.4	1.21	0.05
TDS	2592	2400	2690	2561	500
sulfate	1424	1362	1510	1432	250
thallium	0.058	0.115	0.071	0.081	0.002

Barrick Mercur Mine
16550-005-031
Report Dump Leach Area No. 1
May 17, 1993

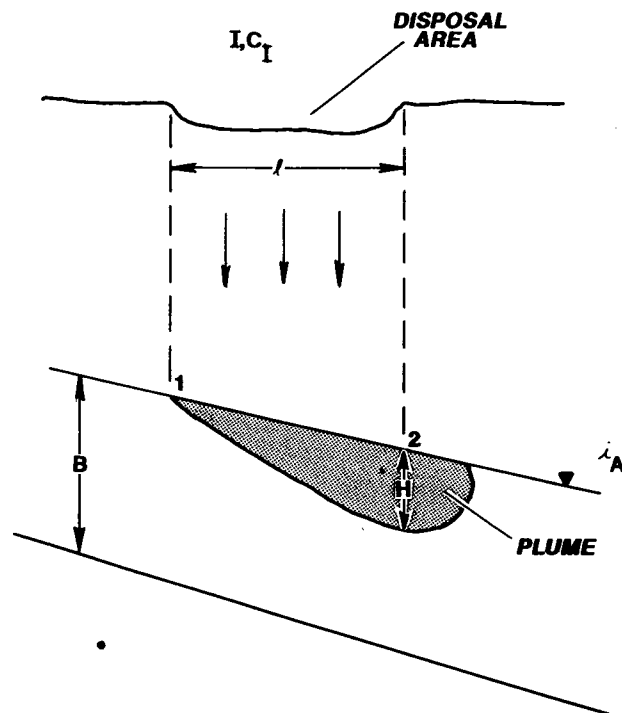
TABLE 3
WATER CHEMISTRY FROM MONITOR WELL 9

Date Sampled	December 3, 1992	January 5, 1993	February 2, 1993	Average	Federal Primary and Secondary MCLs
arsenic	<0.01	<0.01	<0.01	<0.01	0.05
manganese	0.033	0.034	0.032	0.033	0.05
TDS	466	459	456	460	500
sulfate	92	83.1	85	87	250
thallium	<0.01	<0.01	<0.01	<0.01	0.002

Barrick Mercur Mine
16550-005-031
Report Dump Leach Area No. 1
May 17, 1993

TABLE 4
PREDICTED CONCENTRATIONS FROM THE MIXING MODEL

CONSTITUENT	CASE 1 ppm	CASE 2 ppm	MCL or SMCL ppm
arsenic	0.11	0.03	0.05
manganese	0.08	0.05	0.05
TDS	468	462	500-1,000
sulfate	130	99	250-500
thallium	0.004	0.001	0.002



EXPLANATION

I = INFILTRATION RATE

C_I = CONCENTRATION IN INFILTRATED WATER

l = LENGTH OF DISPOSAL AREA

λ_A = HYDRAULIC GRADIENT BETWEEN POINTS 1 AND 2

H = MIXING DEPTH

B = AQUIFER THICKNESS

ASSUME: LENGTH (l) OF DISPOSAL AREA IS PARALLEL TO FLOW
WIDTH (w) OF DISPOSAL AREA IS PERPENDICULAR TO FLOW

SCHEMATIC DIAGRAM OF MIXING MODEL COMPONENTS

Dames & Moore

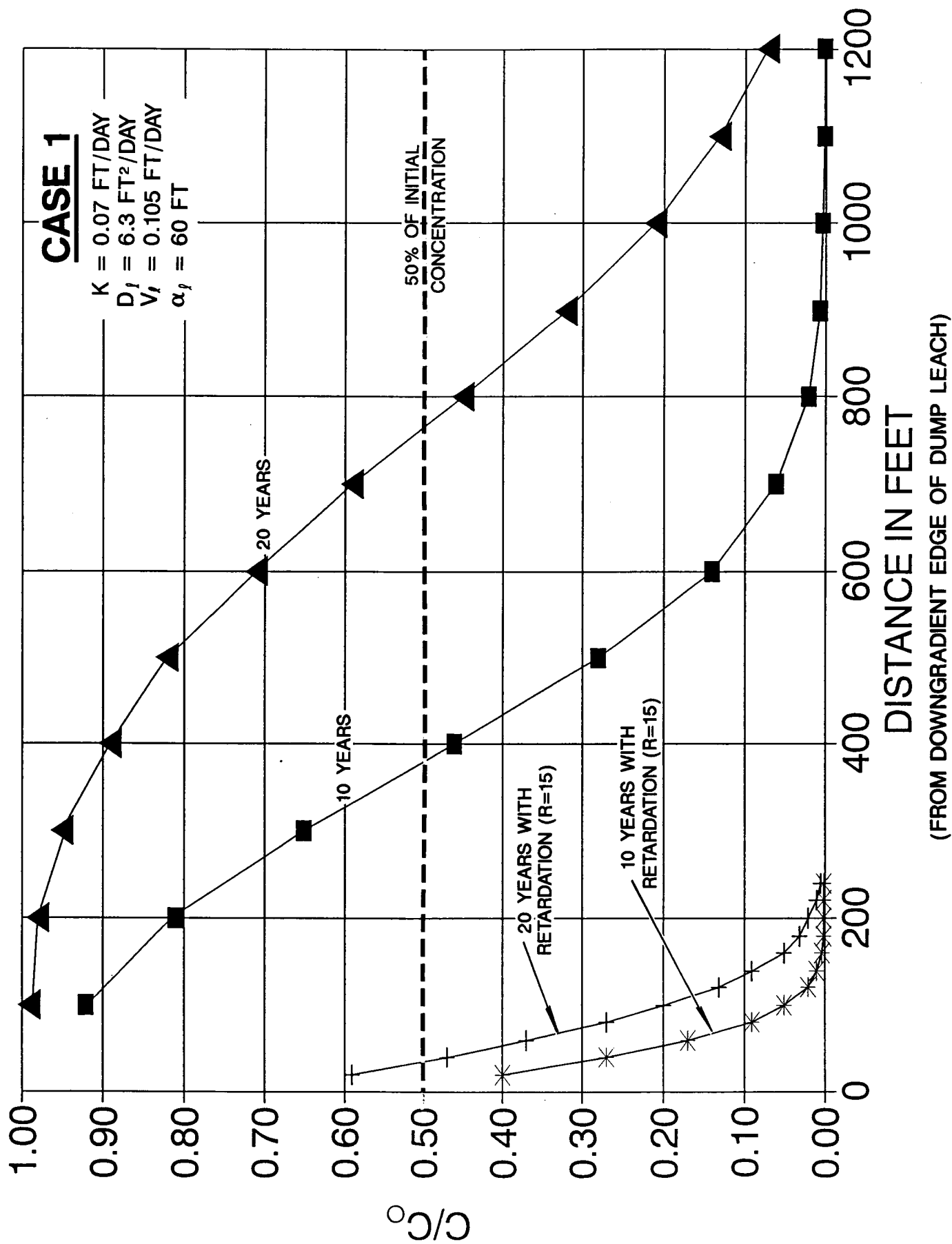


FIGURE 2

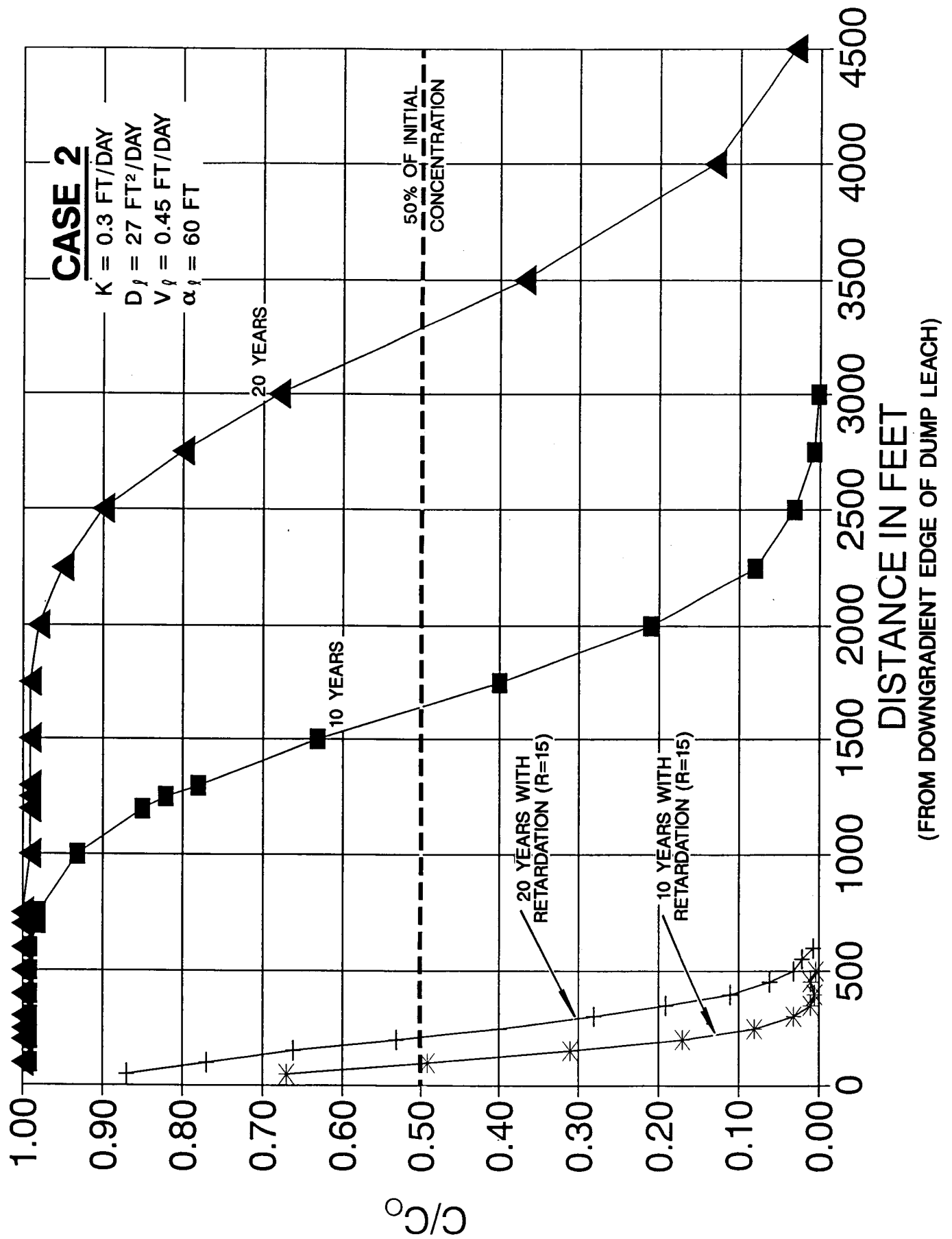


FIGURE 3

APPENDIX

DATABASE PRINTOUT FROM MIXING MODEL
COMPUTER OUTPUT FROM ODAST, 1-D SOLUTE TRANSPORT MODEL.

Barrick 16550 005 031

May 14, 1993

Evaluation of Dump Leach Area #1

Mixing Model

Case 1 - Low Permeability and Low Dispersivity

$$C'A = (QICI + QACA)/(QI+QA)$$

1) Calculate Concentrations CA and CI

Sampling Event	DLA #1			Avg	mixed
	1-26-93	7-14-92	1-15-92		
arsenic	1.98	2.93	2.8	2.57	0.50
manganese	1.4	0.796	1.44	1.212	0.233
TDS	2690	2400	2592	2561	493
sulfate	1510	1362	1424	1432	276
thallium	0.071	0.115	0.058	0.081	0.016

Sampling Event	MW-9			Avg
	2-2-93	1-5-93	12-3-92	
arsenic	0.01	0.01	0.01	0.01
manganese	0.032	0.034	0.033	0.033
TDS	456	459	466	460
sulfate	85	83.1	92	87
thallium	0.01	0.01	0.01	0.01

2) Define Constants

L= 600 ft
W= 300 ft
QI= 1035000 gal/yr= 379 ft³/day
B= 400 ft
KA= 0.07 ft/day
IA= 0.15 ft/ft
VA= 0.0105 ft/day
ALPHAT= 12 ft
Inf= 0.0021 ft/day

3) Calculate $u = L_{inf}/BVA$

$u = 54156.16$

4) Calculate Depth of Mixing $H = ((2 * \alpha * I)^{1/2}) + (B * (1 - (e^{-u})))$

$H = 520$

if $H > B$ then $H = B$ $H = 400$

5) Calculate $AA = W * H$

$AA = 120000$

6) Calculate $QA = KAAAIA$

$QA = 1260 \text{ ft}^3/\text{day}$

7) Calculate $C'A$

	calculated	MCL	
$C'A_{as} =$	0.11	0.05	Assume background is zero
$C'A_{as} =$	0.12	0.05	Assume background is 0.01
$C'A_{mn} =$	0.08	0.05	
$C'ATDS =$	467.94	500-1000	
$C'Asulf =$	130.44	250-500	
$C'A_{thall} =$	0.004	0.002	Assume background is zero
$C'A_{thall} =$	0.011	0.002	Assume background is 0.01

Barrick 16550 005 031

May 14, 1993

Evaluation of Dump Leach Area #1

Mixing Model

Case 2 - High Permeability and High Dispersivity

$$C'A = (QICI + QACA)/(QI+QA)$$

1) Calculate Concentrations CA and CI

DLA #1					
Sampling Event	1-26-93	7-14-92	1-15-92	Avg	mixed
arsenic	1.98	2.93	2.8	2.57	0.50
manganese	1.4	0.796	1.44	1.212	0.233
TDS	2690	2400	2592	2561	493
sulfate	1510	1362	1424	1432	276
thallium	0.071	0.115	0.058	0.081	0.016

MW-9				
Sampling Event	2-2-93	1-5-93	12-3-92	Avg
arsenic	0.01	0.01	0.01	0.01
manganese	0.032	0.034	0.033	0.033
TDS	456	459	466	460
sulfate	85	83.1	92	87
thallium	0.01	0.01	0.01	0.01

2) Define Constants

L= 600 ft
W= 300 ft
QI= 1035000 gal/yr= 379 ft³/day
B= 400 ft
KA= 0.3 ft/day
IA= 0.15 ft/ft
VA= 0.045 ft/day
ALPHAT= 20 ft
Inf= 0.0021 ft/day

3) Calculate $u = L \ln f / BVA$

$u = 12636.44$

4) Calculate Depth of Mixing $H = ((2 * \alpha * l)^{1/2}) + (B * (1 - (e^{-u})))$

$H = 554.9193$

if $H > B$ then $H = B$ $H = 400$

5) Calculate $AA = W * H$

$AA = 120000$

6) Calculate $QA = KAAAIA$

$QA = 5400 \text{ ft}^3/\text{day}$

7) Calculate $C'A$

	calculated	MCL	
$C'A_{as} =$	0.03	0.05	Assume background is zero
$C'A_{as} =$	0.04	0.05	Assume background is 0.01
$C'A_{mn} =$	0.05	0.05	
$C'ATDS =$	462	500-1000	
$C'Asulf =$	99	250-500	
$C'A_{thall} =$	0.001	0.002	Assume background is zero
$C'A_{thall} =$	0.010	0.002	Assume background is 0.01

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .11 D= 6.30 R=1.0 LAMBDA= .000 ALPHA= .000 TO= 25.0

T(YEARS)	X= 100.	X= 200.	X= 300.	X= 400.	X= 500.	X= 600.
10.0	.9220D+00	.8118D+00	.6478D+00	.4556D+00	.2760D+00	.1424D+00
20.0	.9915D+00	.9765D+00	.9466D+00	.8948D+00	.8160D+00	.7114D+00

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .11 D= 6.30 R=1.0 LAMBDA= .000 ALPHA= .000 TO= 25.0

T(YEARS)	X= 700.	X= 800.	X= 900.	X=1000.	X=1100.	X=1200.
10.0	.6137D-01	.2196D-01	.6483D-02	.1571D-02	.3116D-03	.5043D-04
20.0	.5852D+00	.4505D+00	.3221D+00	.2125D+00	.1287D+00	.7126D-01

cool
R

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .11 D= 6.30 R=*** LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 20.	X= 40.	X= 60.	X= 80.	X= 100.	X= 120.
10.0	.4022D+00	.2712D+00	.1671D+00	.9352D-01	.4729D-01	.2151D-01
20.0	.5809D+00	.4720D+00	.3678D+00	.2742D+00	.1950D+00	.1321D+00

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .11 D= 6.30 R=*** LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 140.	X= 160.	X= 180.	X= 200.	X= 220.	X= 240.
10.0	.8769D-02	.3193D-02	.1036D-02	.2987D-03	.7713D-04	.1758D-04
20.0	.8502D-01	.5192D-01	.3004D-01	.1645D-01	.8509D-02	.4156D-02

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=1.0 LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 250.	X= 500.	X= 750.	X=1000.	X=1250.	X=1500.
10.0	.9995D+00	.9962D+00	.9807D+00	.9305D+00	.8158D+00	.6272D+00
20.0	.1000D+01	.1000D+01	.1000D+01	.9999D+00	.9995D+00	.9981D+00

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=1.0 LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X=1750.	X=2500.	X=3000.	X=3500.	X=4000.	X=4500.
10.0	.4023D+00	.2543D-01	.1020D-02	.1255D-04	.4587D-07	.4906D-10
20.0	.9935D+00	.8971D+00	.6772D+00	.3658D+00	.1262D+00	.2592D-01

Case 2

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=1.0 LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 250.	X= 500.	X= 750.	X=1000.	X=1250.	X=1500.
10.0	.9995D+00	.9962D+00	.9807D+00	.9305D+00	.8158D+00	.6272D+00
20.0	.1000D+01	.1000D+01	.1000D+01	.9999D+00	.9995D+00	.9981D+00

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=1.0 LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X=1750.	X=2000.	X=2250.	X=2500.	X=2750.	X=3000.
10.0	.4023D+00	.2069D+00	.8295D-01	.2543D-01	.5888D-02	.1020D-02
20.0	.9935D+00	.9810D+00	.9525D+00	.8971D+00	.8057D+00	.6772D+00

Color 2

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=1.0 LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 100.	X= 200.	X= 300.	X= 400.	X= 500.	X= 600.
10.0	.9999D+00	.9997D+00	.9992D+00	.9982D+00	.9962D+00	.9924D+00
20.0	.1000D+01	.1000D+01	.1000D+01	.1000D+01	.1000D+01	.1000D+01

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=1.0 LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 700.	X= 800.	X= 900.	X=1000.	X=1200.	X=1300.
10.0	.9856D+00	.9744D+00	.9567D+00	.9305D+00	.8450D+00	.7836D+00
20.0	.1000D+01	.1000D+01	.9999D+00	.9999D+00	.9996D+00	.9994D+00

2200 2
R

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=*** LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 50.	X= 100.	X= 150.	X= 200.	X= 250.	X= 300.
10.0	.6738D+00	.4890D+00	.3133D+00	.1748D+00	.8398D-01	.3448D-01
20.0	.8654D+00	.7712D+00	.6552D+00	.5268D+00	.3982D+00	.2814D+00

DIMENSIONLESS CONCENTRATION C/CO FOR

V= .45 D= 27.00 R=*** LAMBDA= .000 ALPHA= .000 T0= 25.0

T(YEARS)	X= 350.	X= 400.	X= 450.	X= 500.	X= 550.	X= 600.
10.0	.1201D-01	.3558D-02	.8850D-03	.1849D-03	.3240D-04	.4743D-05
20.0	.1850D+00	.1128D+00	.6354D-01	.3319D-01	.1591D-01	.7006D-02